The JPL RL06 GRACE Gravity Solutions

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Gravity Geoid and Height Systems 2

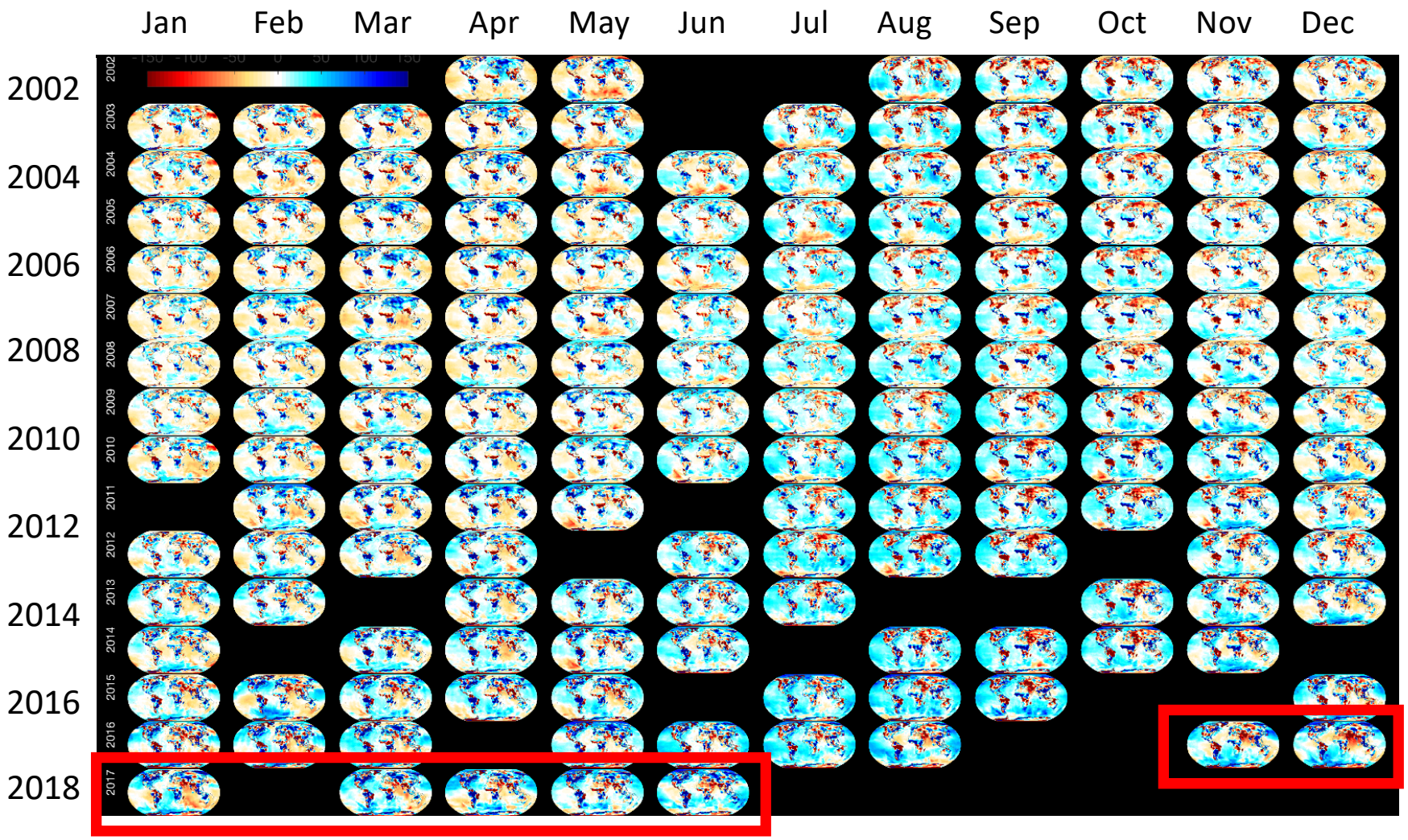
Copenhagen, Denmark

RL06 Data Products

- Unconstrained Monthly Spherical Harmonic Solutions
  - 60 x 60
  - 96 x 96
  - 60 x 30 in months with deep repeat orbits
- Constrained 3^{o} Spherical Cap Mascon Solution
  - Solution with Coastline Resolution Improvement (CRI) Filter
  - Solution without CRI Filter
  - Calibrated errors are provided

- New Filename Definitions and YAML headers in RL06 harmonic products
- Mascon solutions are NetCDF format
- Solutions can be accessed through PODAAC or GRACE Tellus (grace.jpl.nasa.gov)

Data Overview



Months with only GRACE-A Accelerometer Data

Data and Parameterization

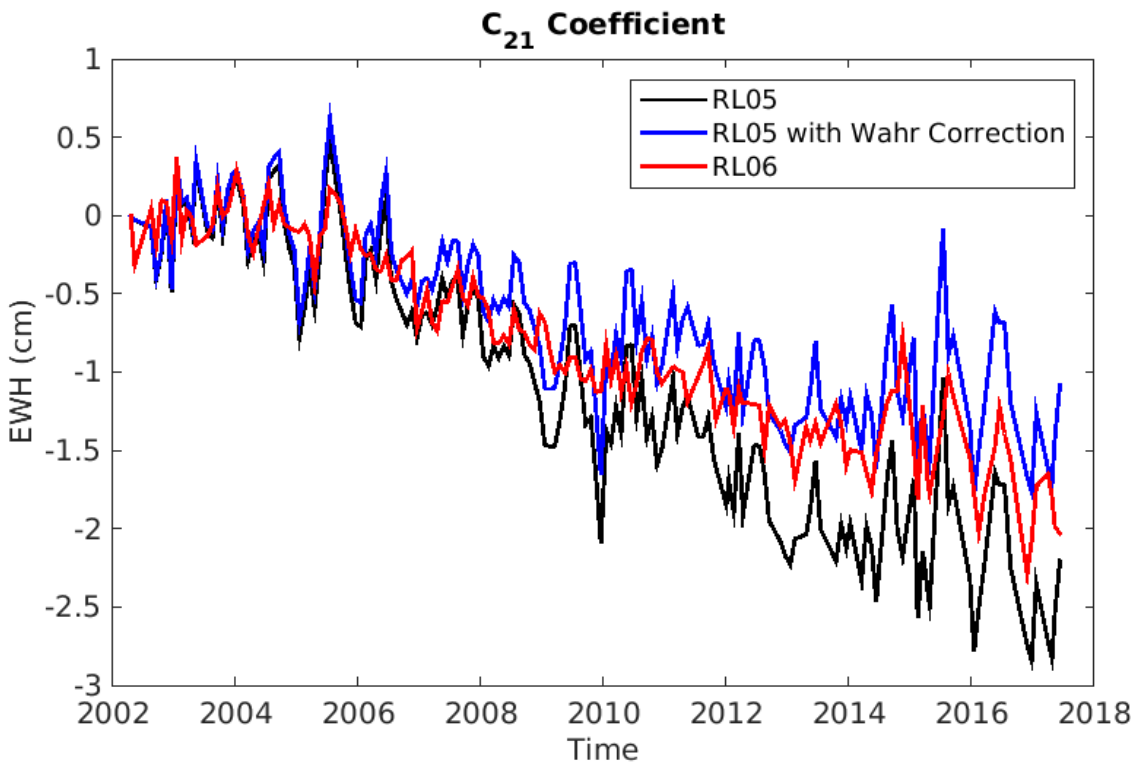
		RL05	RL06
Data Used *Only for Single Accelerometer months	Harmonics	ACC1B V02 (5-second rate) KBR1B V02 (5-second rate) SCA1B V02 (5-second rate) GPS1B V02 (300-second rate)	ACC1B V02 (5-second rate) **KBR1B V03 (5-second rate)** **SCA1B V03 (5-second rate)** **GPS1B V02 (30-second rate) - downweighted** ***ACT1B V02 (5-second rate)**
	Mascons	ACC1B V02 (5-second rate) KBR1B V02 (5-second rate) SCA1B V02 (5-second rate)	ACC1B V02 (5-second rate) **KBR1B V03 (5-second rate)** **SCA1B V03 (5-second rate)** **GPS1B V02 (30-second rate) - downweighted** ***ACT1B V02 (5-second rate)**
Parameterization *Only for Single Accelerometer months	Harmonics and Mascons	Satellite States: once per day; GPS phase biases: once per pass; KBR range-rate empirical biases/drifts/once-per-rev: 90 min; Accelerometer Biases/Rates: X and Z daily, Y is 3 hourly; *Empirical accelerations (constant, once/rev) every 90 min in alongtrack and crosstrack	Satellite States: once per day GPS phase biases: once per pass KBR range-rate empirical biases/drifts/once-per-rev: 90 min Accelerometer Biases/Rates: X and Z daily, Y is 3 hourly **Full Accelerometer Scale Matrix: daily (Klinger et al., 2016)** *Empirical accelerations (constant, once/rev) every 90 min in alongtrack and crosstrack

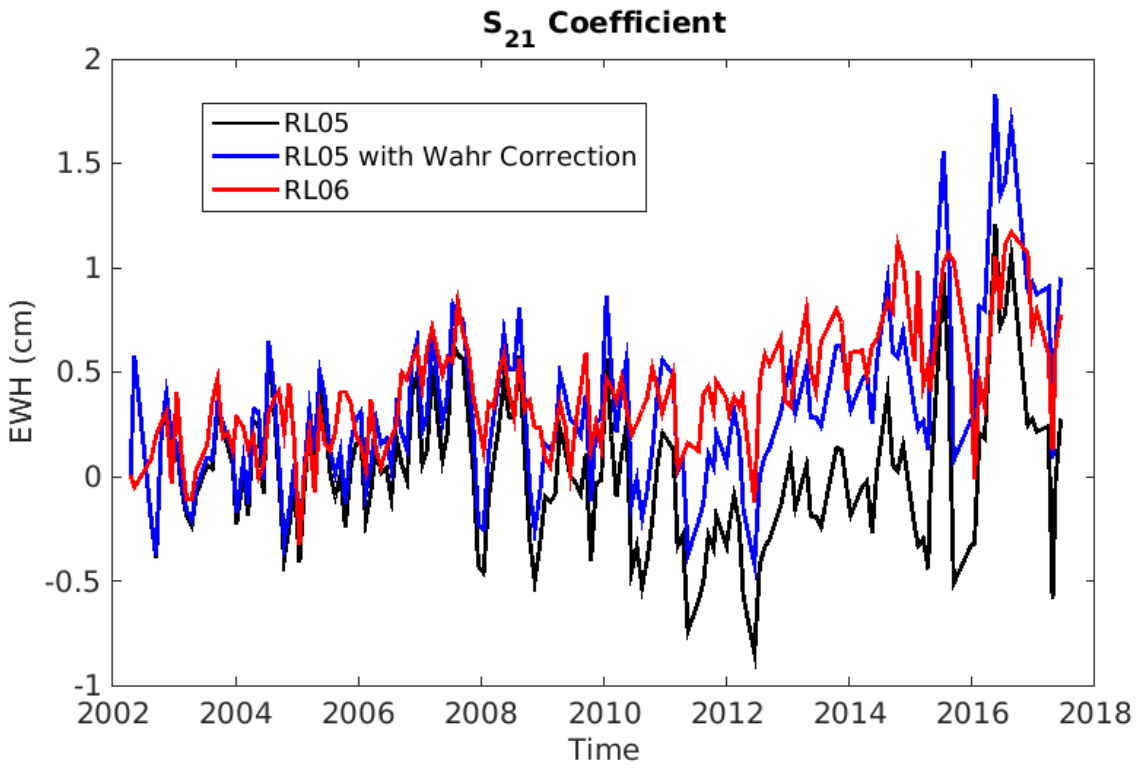
Background models

	RL05	RL06	Remarks
Static Field	gif48 180x180	ggm05c 360x360	Epoch changes from 01/07 to 01/08; earthquakes included in the static field
Atmosphere/Ocean Dealiasing Product	AOD RL05 6-hr, 100x100	AOD RL06 3-hr, 180x180	GAE, GAF, GAG products no longer needed
Ocean Tides	GOT4.7 90x90	FES2014 180x180	Changes from 90x90 to 180x180
Air Tides	Ray and Ponte, 2003	Ray and Ponte, 2003	S1 and S2, 100x100
Mean Pole	IERS2010	Linear Mean Pole (Ries, 2017)	Correction to C_{21} recommended by Wahr et al., 2015 is no longer needed
N-body Perturbations	DE421	DE430	

C21/S21

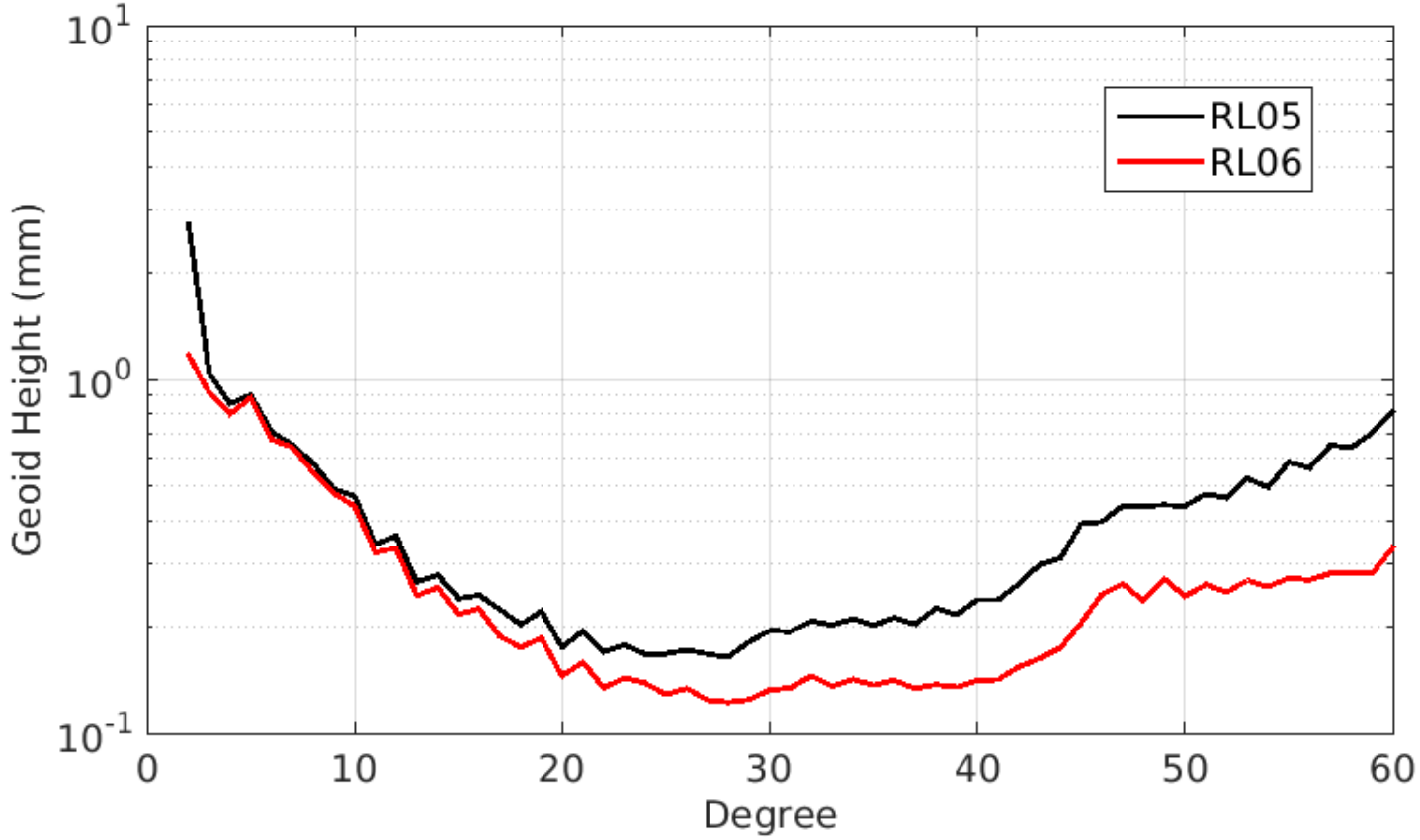

GRACE / GRACE-FO


C21 Coefficient
RL05
RL05 with Wahr Correction
RL06
EWH (cm)
Time
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
2002
2004
2006
2008
2010
2012
2014
2016
2018


S21 Coefficient
RL05
RL05 with Wahr Correction
RL06
EWH (cm)
Time
2
1.5
1
0.5
0
-0.5
-1
2002
2004
2006
2008
2010
2012
2014
2016
2018

Solution Quality: RL05 to RL06

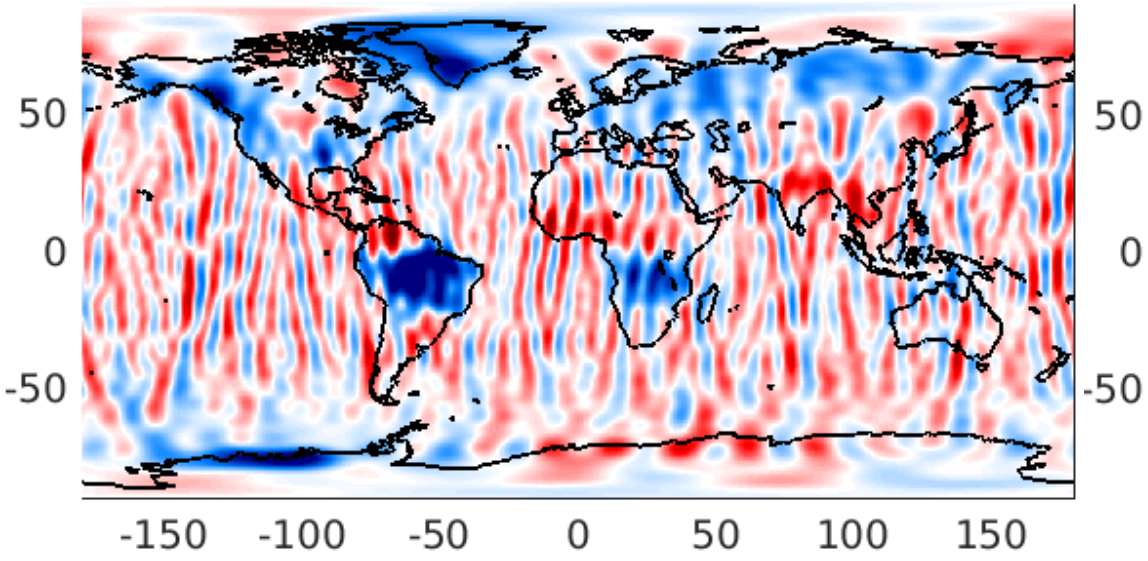
Average over all GRACE months



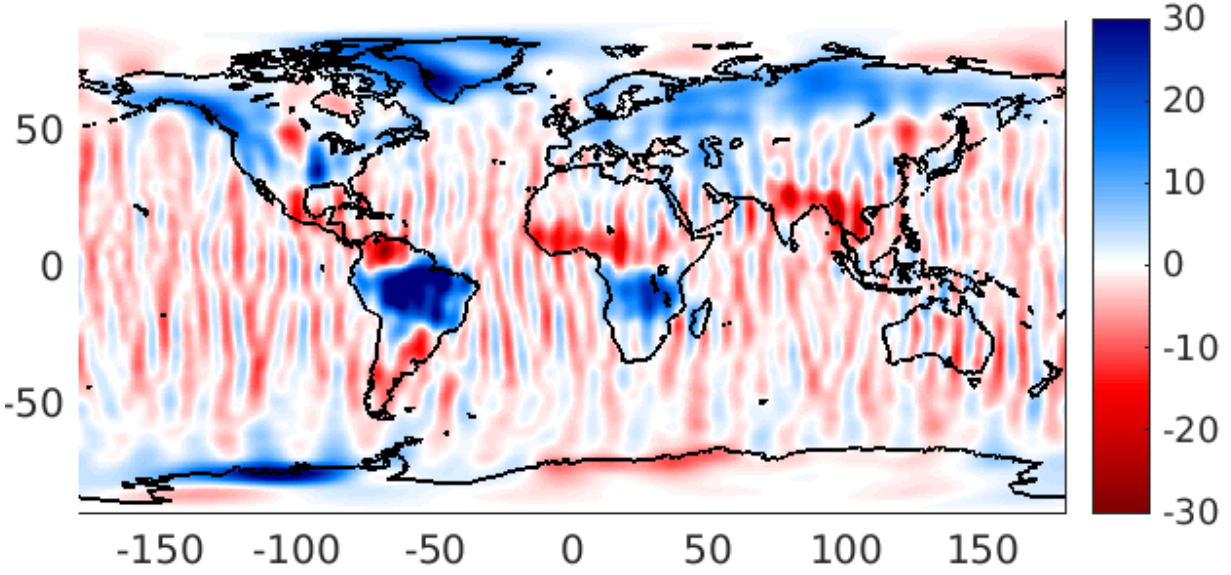
Solution Quality: RL05 to RL06

April 2008 with 300 km Gaussian smoothing

RL05

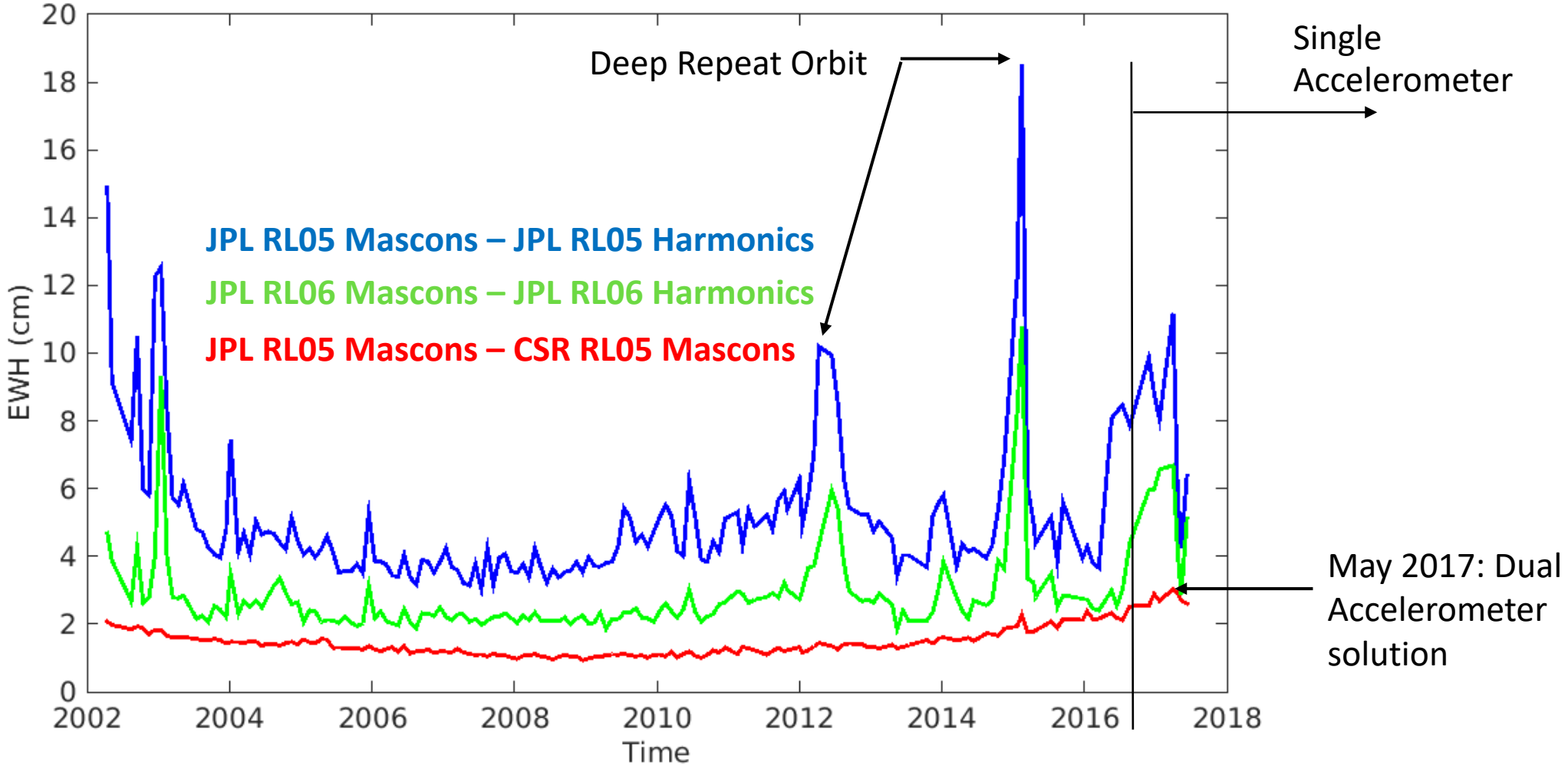


RL06



Solution Quality

Global Spatial RMS of monthly differences between JPL Mascons: Smoothed at 300 km



Single Accelerometer Months

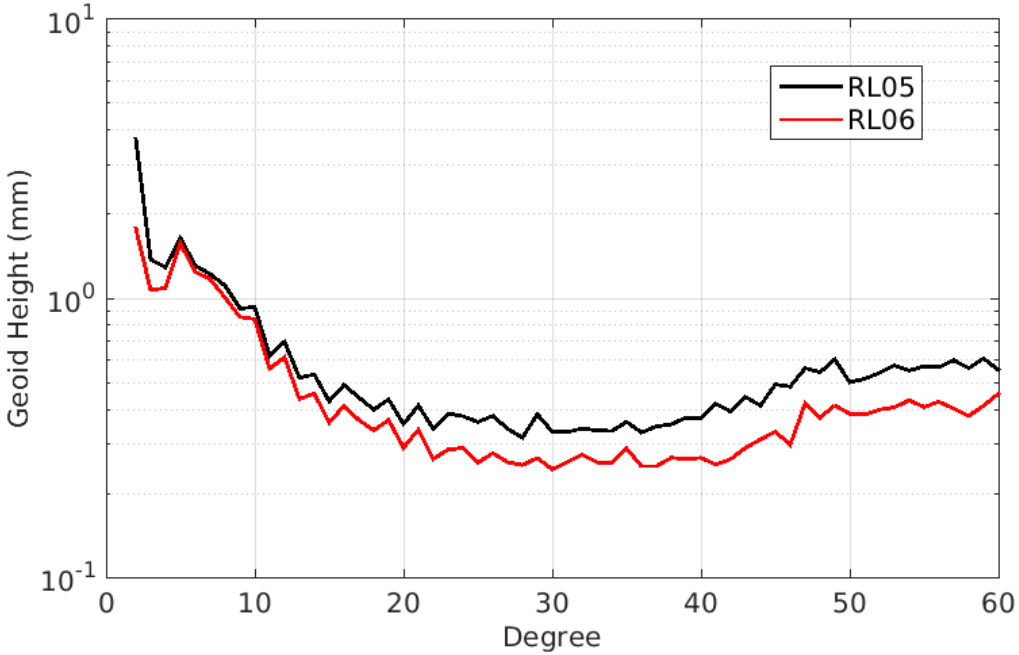
Two accelerometer Solution
Single accelerometer Solution
★ Pitch Bias introduced

Jul	Aug	Sep	Oct	Nov	Dec	
						2016

		★	★	★	★	
Jan	Feb	Mar	Apr	May	Jun	2017

RL06 uses an improved accelerometer transplant from GRACE-A to GRACE-B which accounts for thruster firings on GRACE-B. (Bandikova et al., in prep.)

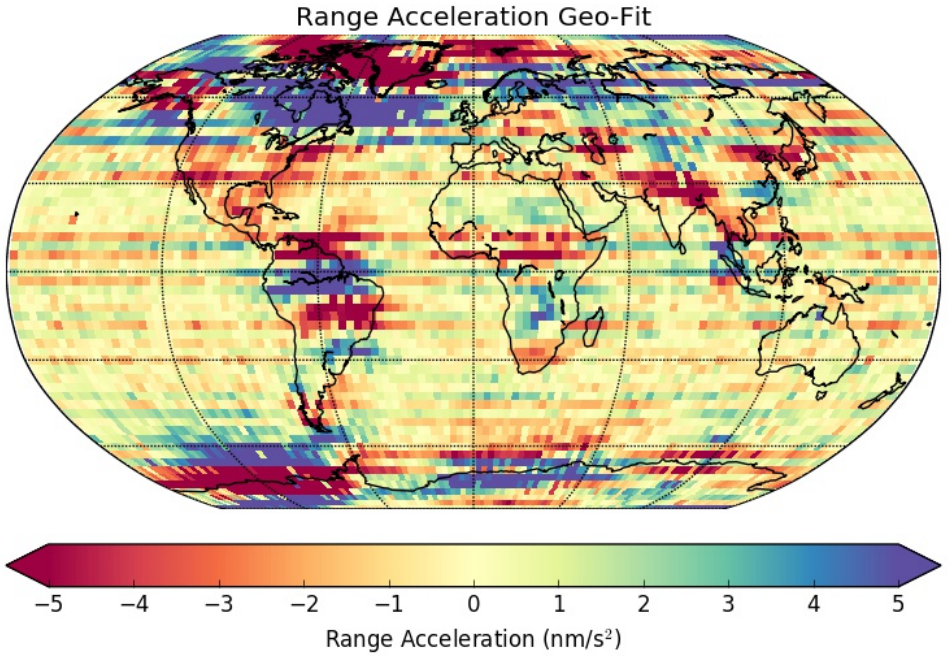
Average over single accelerometer months

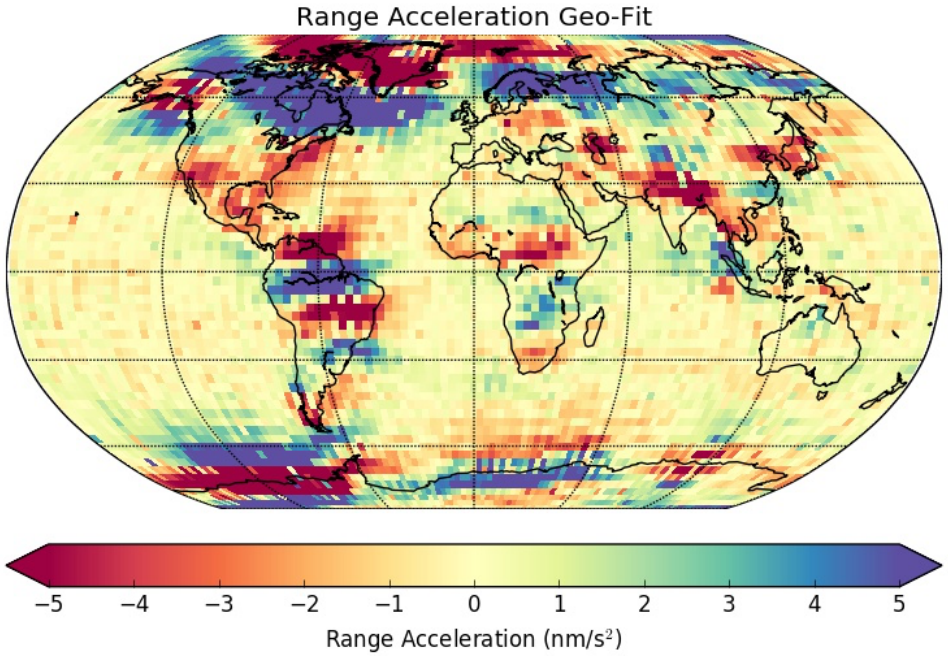


Pitch Bias degradation is reduced (May 2017)

RL05: V02 Level-1 Data
Errors manifest in zonal harmonics leading to latitudinal banding in the gravity field

RL06: V03 Level-1 Data
Reduced high frequency noise in the attitude
Improves the solution

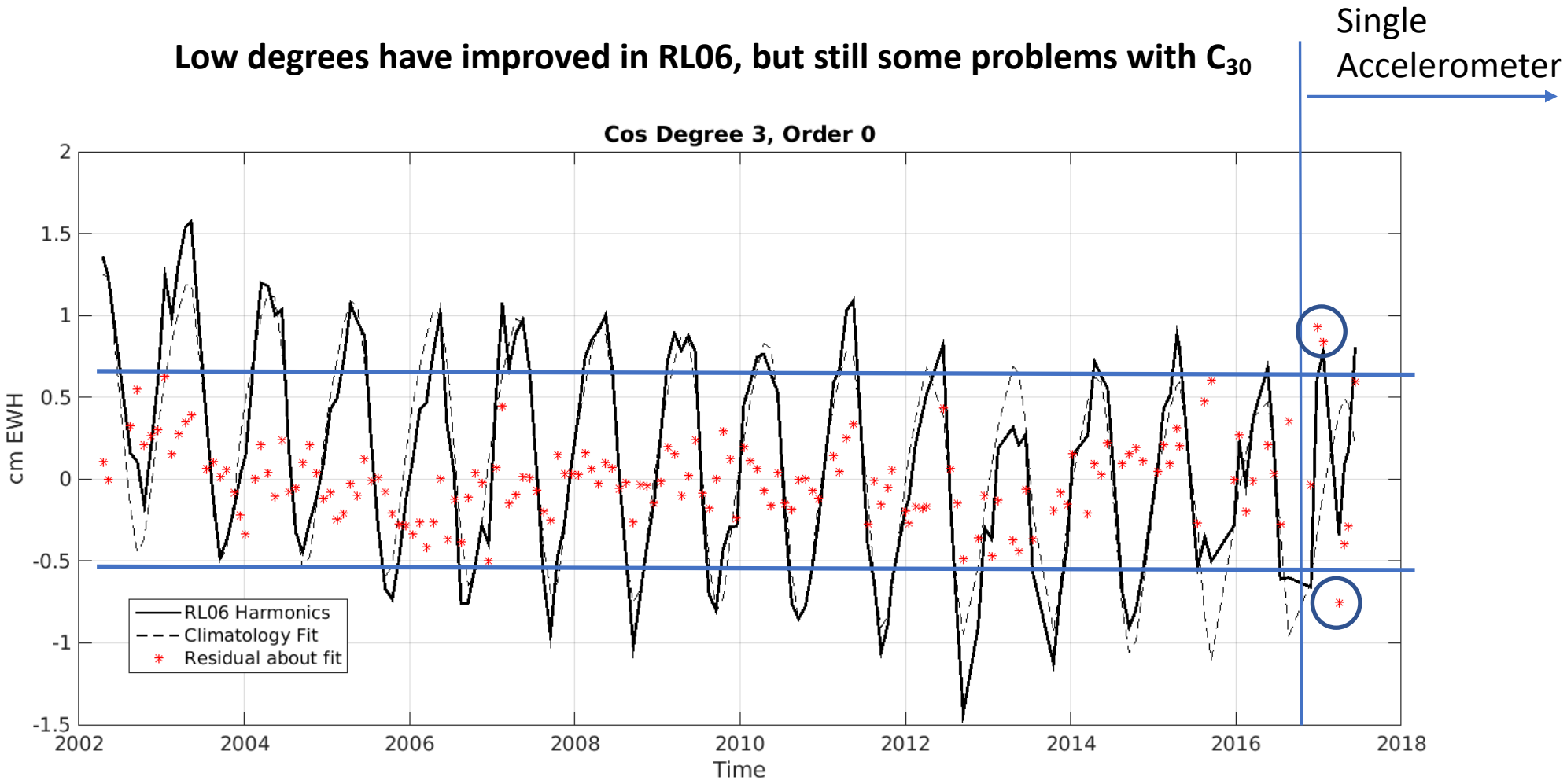




GEO-FIT plots: monthly gravity field correction mapped into range accelerations

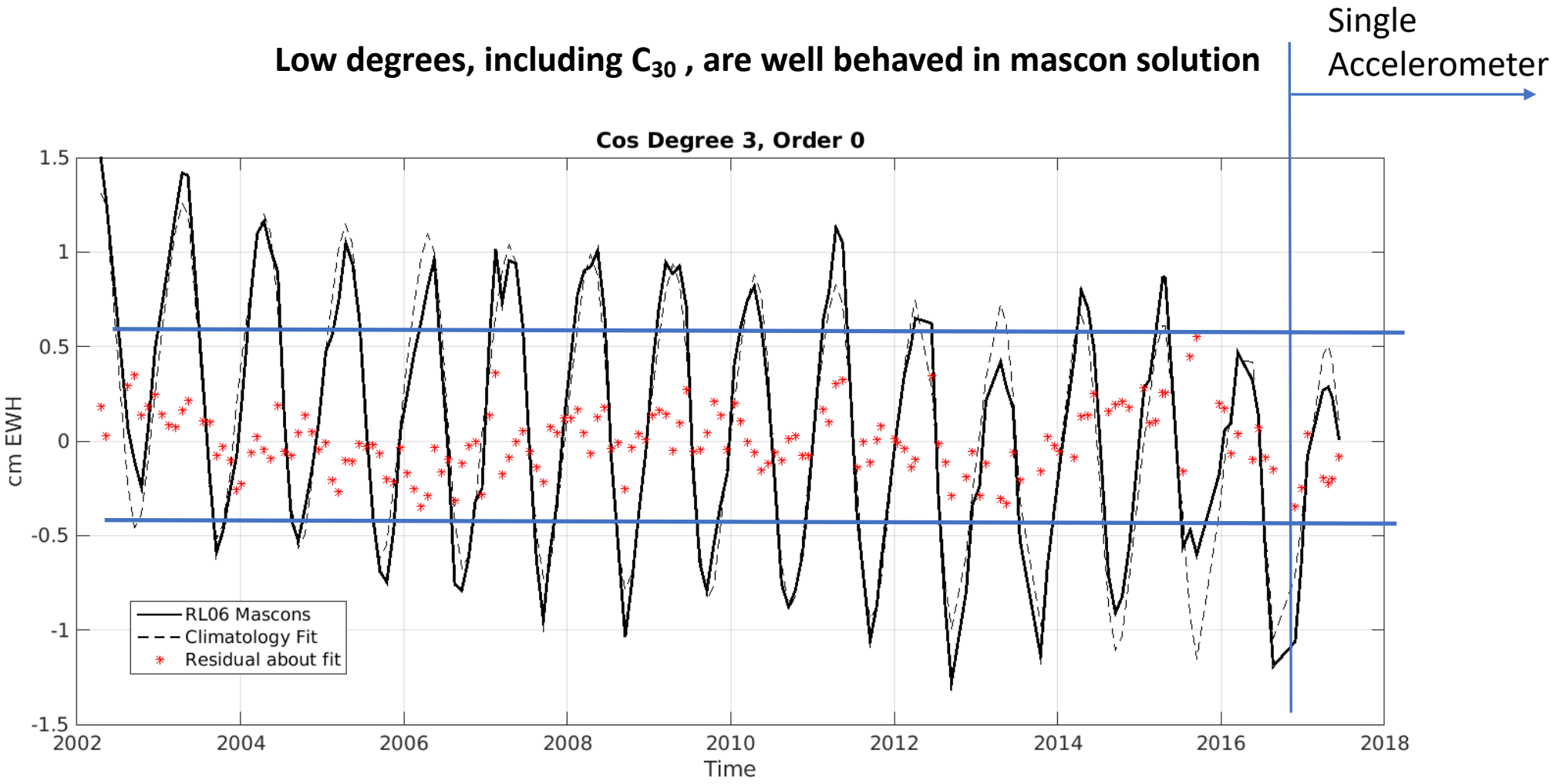
Single Accelerometer – Low Degrees

Low degrees have improved in RL06, but still some problems with C_{30}



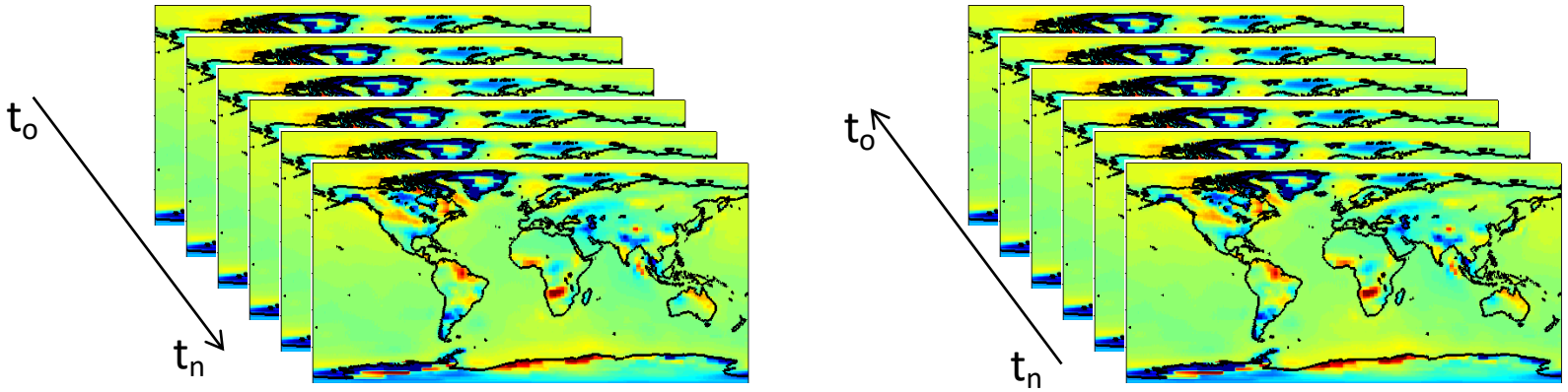
Single Accelerometer – Low Degrees

Low degrees, including C_{30} , are well behaved in mascon solution



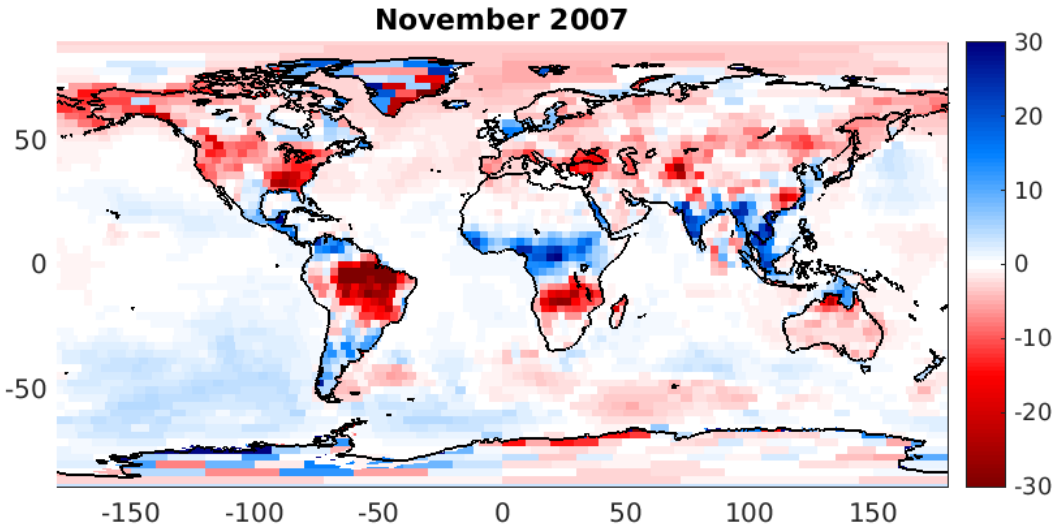
RL06 Mascon Strategy

- RL06 processing strategy is fundamentally the same as RL05
- Improvements made
  - Addition of GPS normal equations
  - Change in the GIA forward model to ICE-6GD
  - Relaxation in initial conditions for time correlation run
  - Earthquake constraints have improved
  - Full Accelerometer Scale Matrix is estimated daily



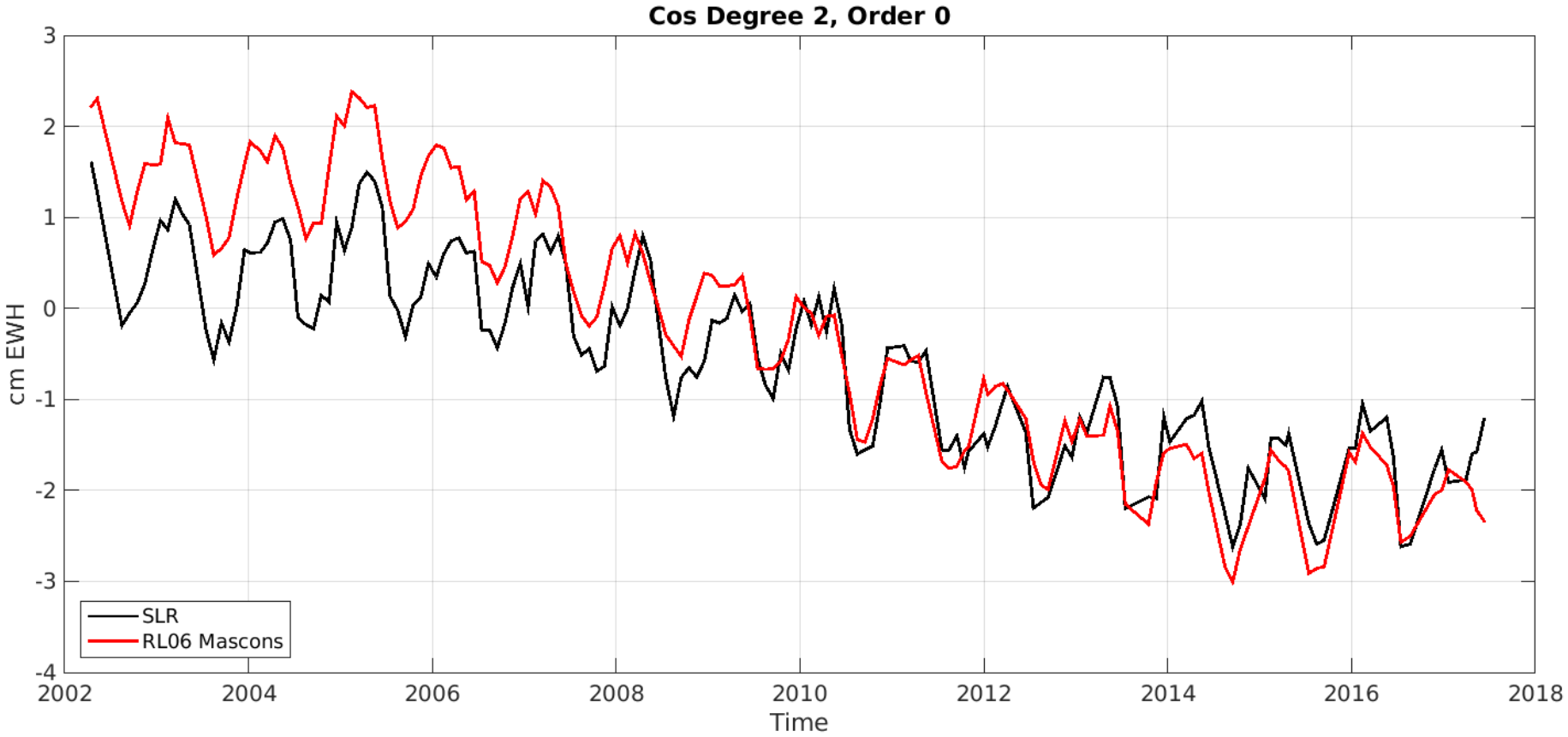
RL06 Mascons

- Improved estimates of single accelerometer months
  - Low degree coefficients are much more reasonable
- Small reduction in noise relative to RL05
- Better estimate of C_{20}
  - SLR-replacement still recommended
- RL06 is very much “in family” with RL05
- Updated GIA correction: ICE-6GD (Peltier et al., 2018)



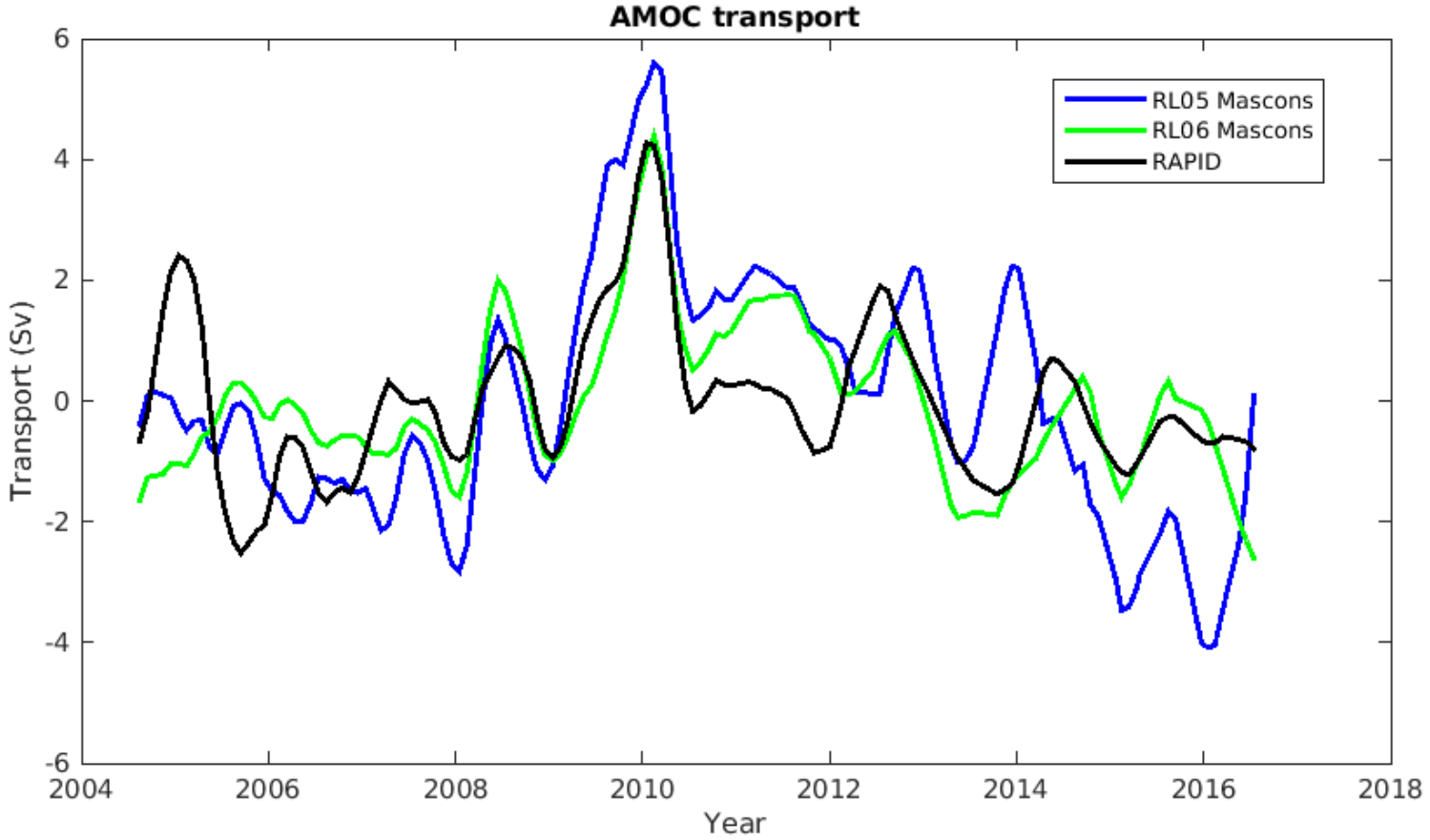
C_{20}

Mascons provide a “reasonable” estimate for C_{20}. The difference in trend with SLR (Cheng et al., 2013) is not well understood. We still replace the C_{20} coefficient with SLR values because of this.



Correlation with AMOC

We compare transport in the Lower North Atlantic Deep Water with the in-situ RAPID array using methods from Landerer et al., 2015



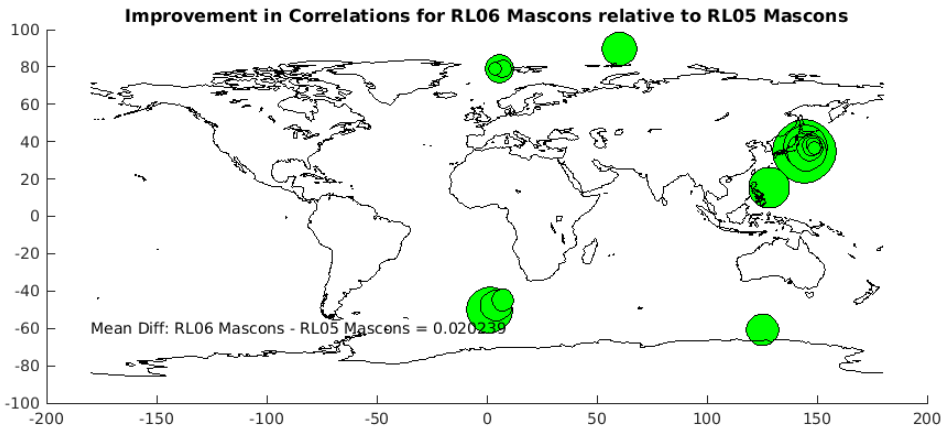
Correlation changes from 0.63 to 0.61

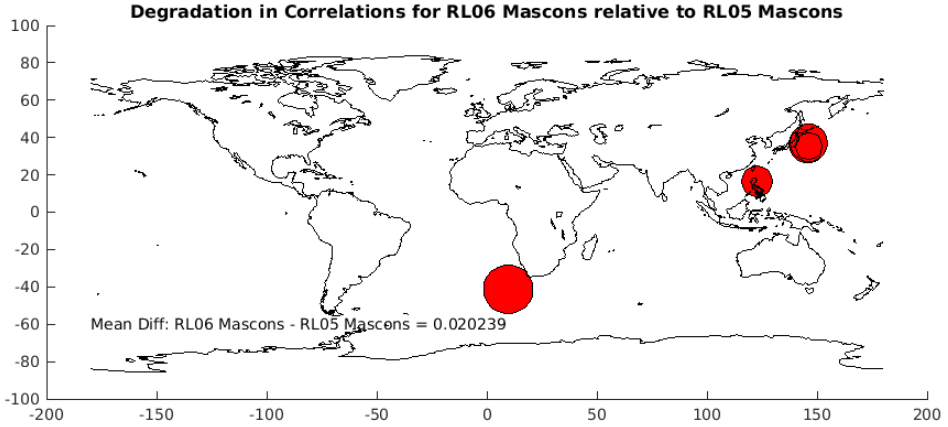
RMS relative to RAPID array decreases from 1.58 Sv to 1.14 Sv.

Comparison with BPRs

Correlation with in-situ data

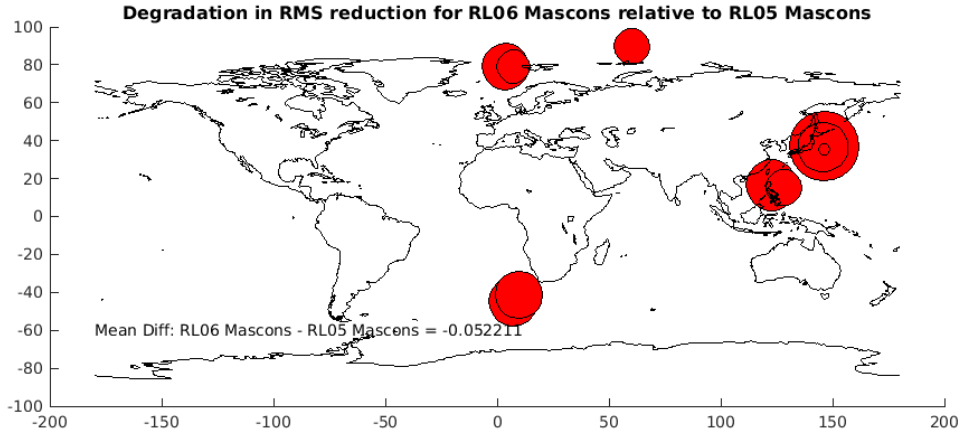
Global improvement in correlation coefficient: 0.02

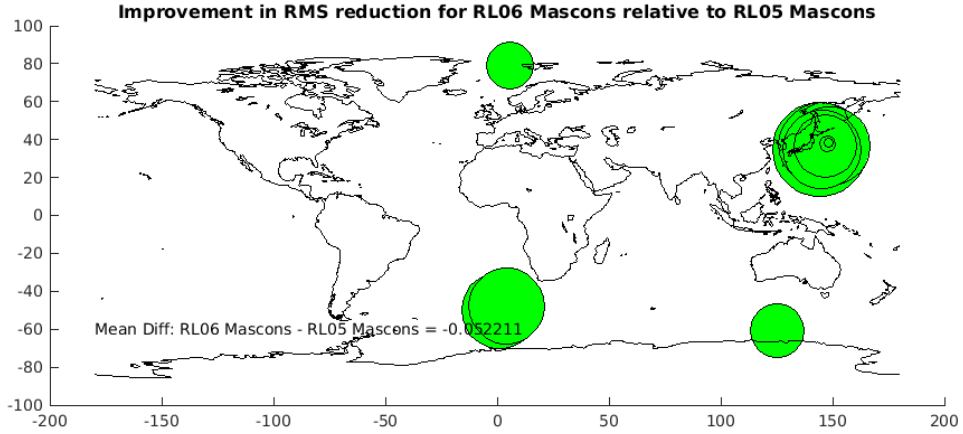




RMS relative to in-situ data

Global improvement in RMS reduction: 0.5 mm

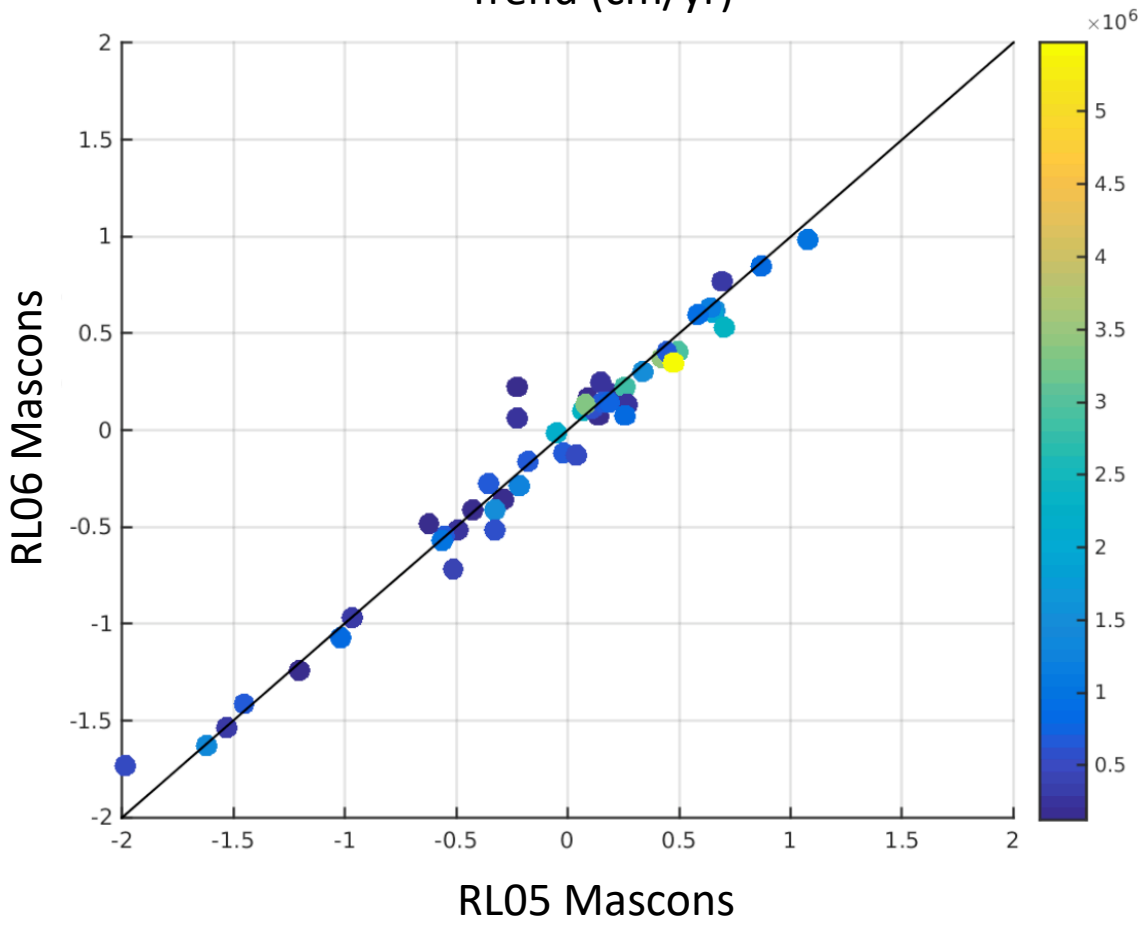




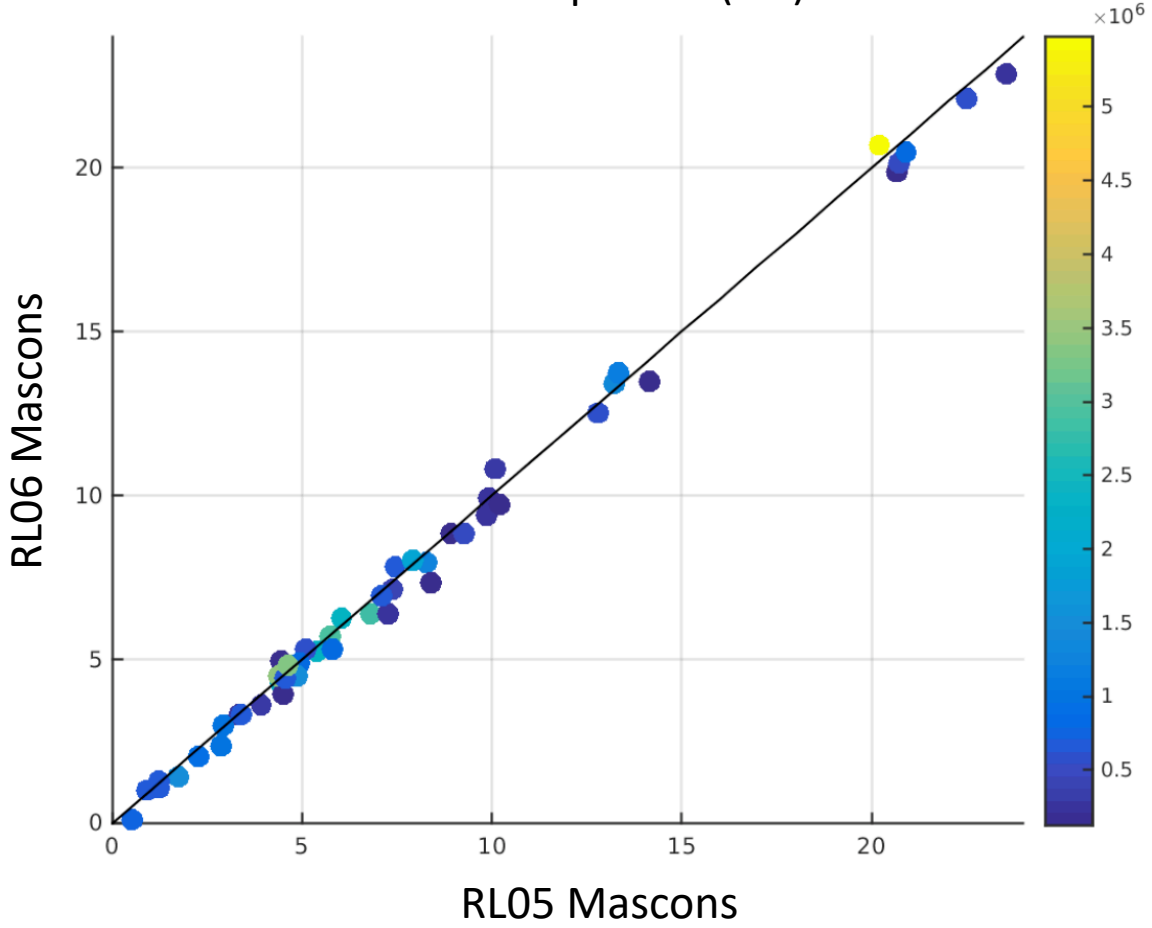
RL05 vs RL06 Mascons

Comparison over 50 hydrological basins

Trend (cm/yr)



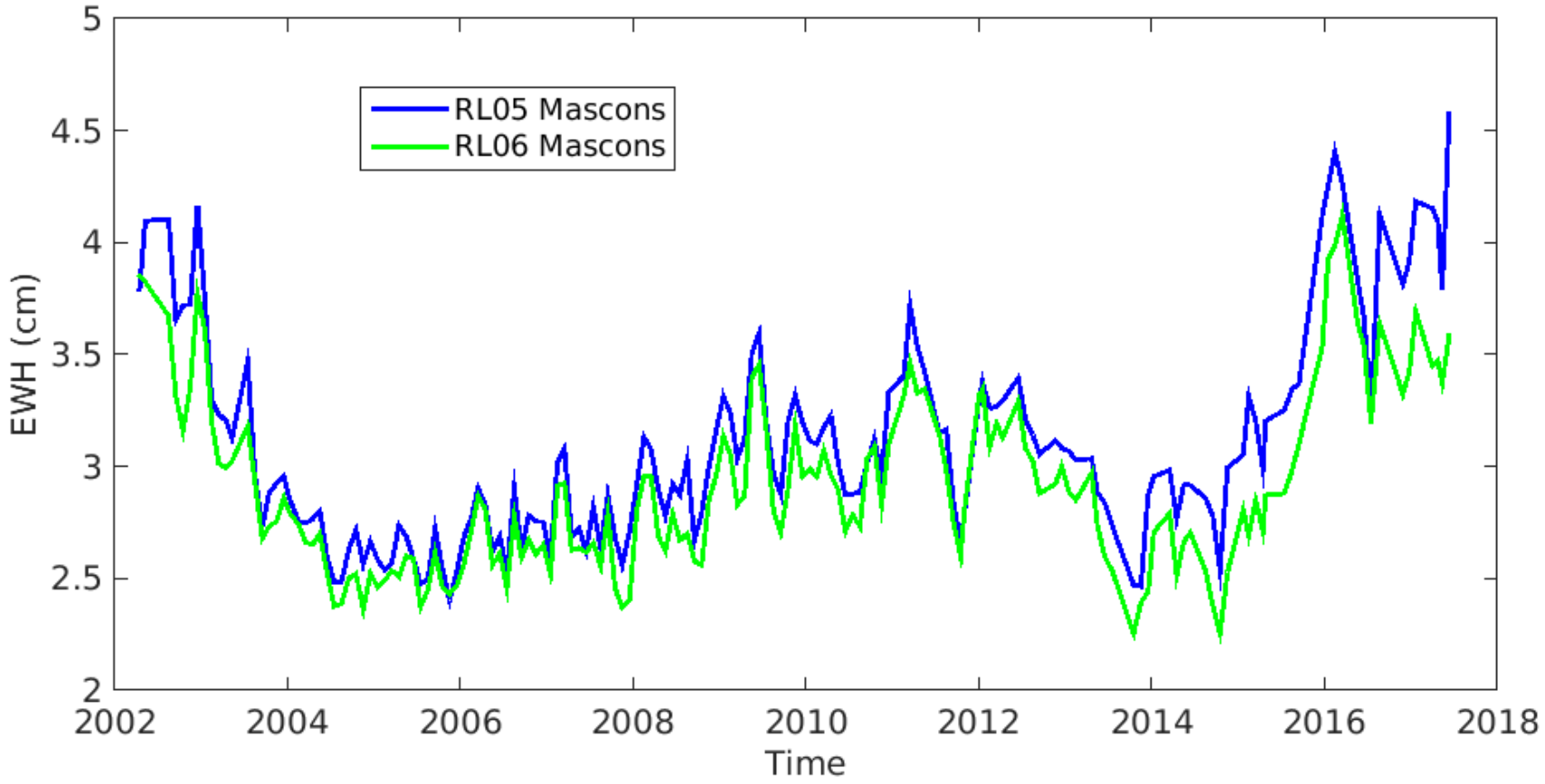
Annual Amplitude (cm)



RL05 vs RL06 Mascons

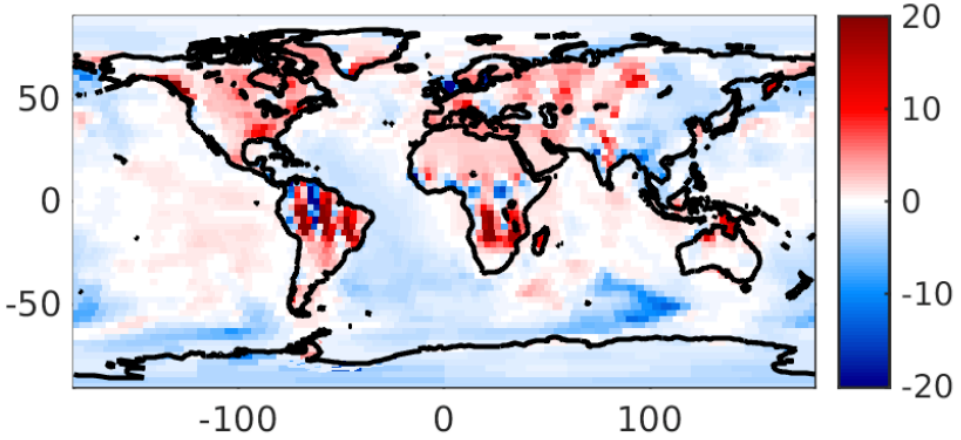
Monthly residuals about a climatology fit to the timeseries

We attribute the slight reduction in residuals in RL06 to a decrease in noise in the solution

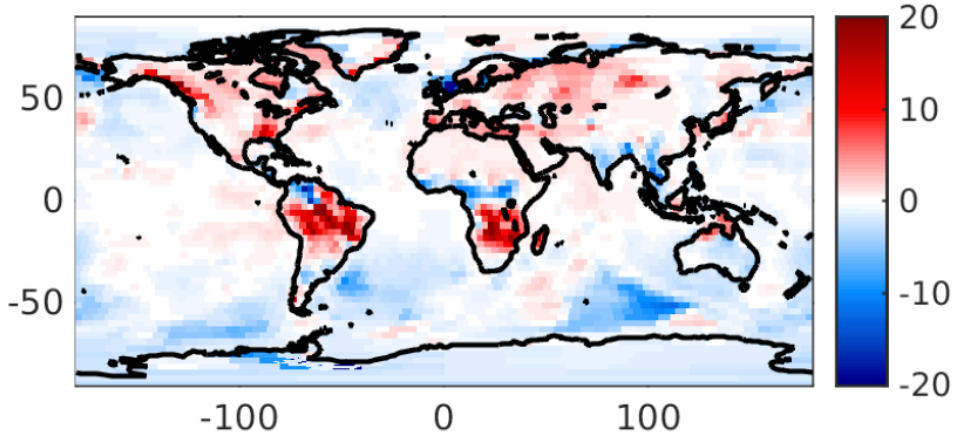


RL05 vs RL06 Mascons

RL05: Jan 2014 – Dec 2013



RL06: Jan 2014 – Dec 2013

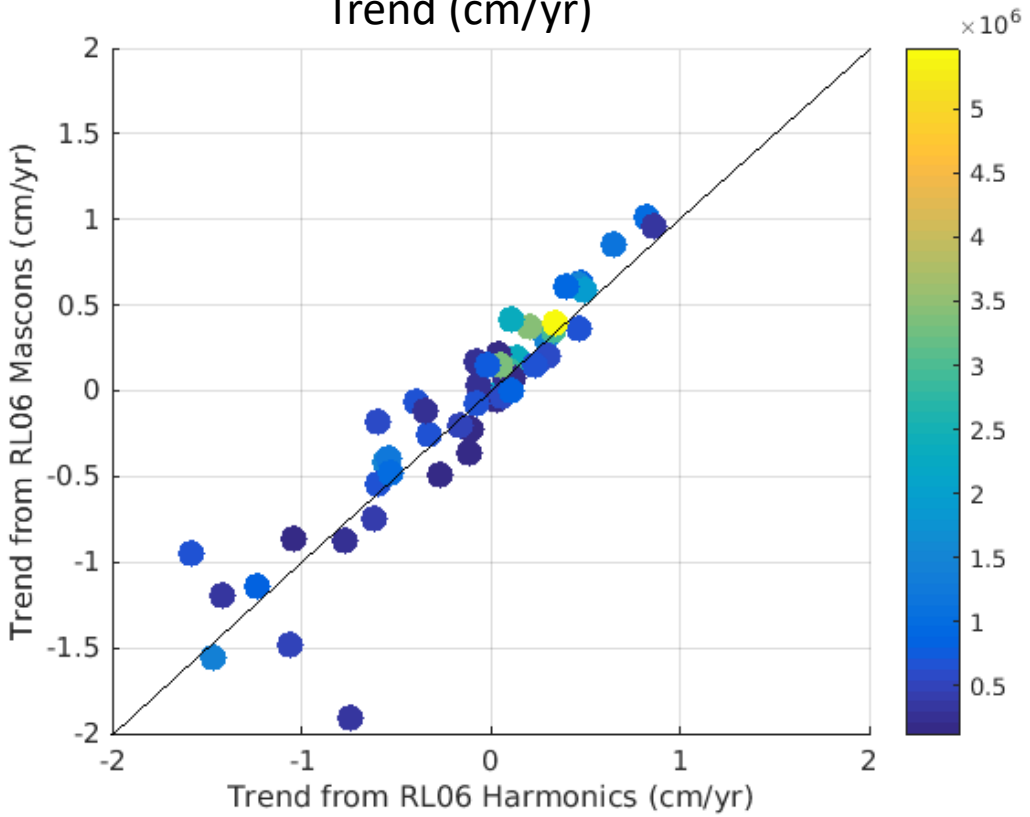


RL06 Mascons vs Harmonics

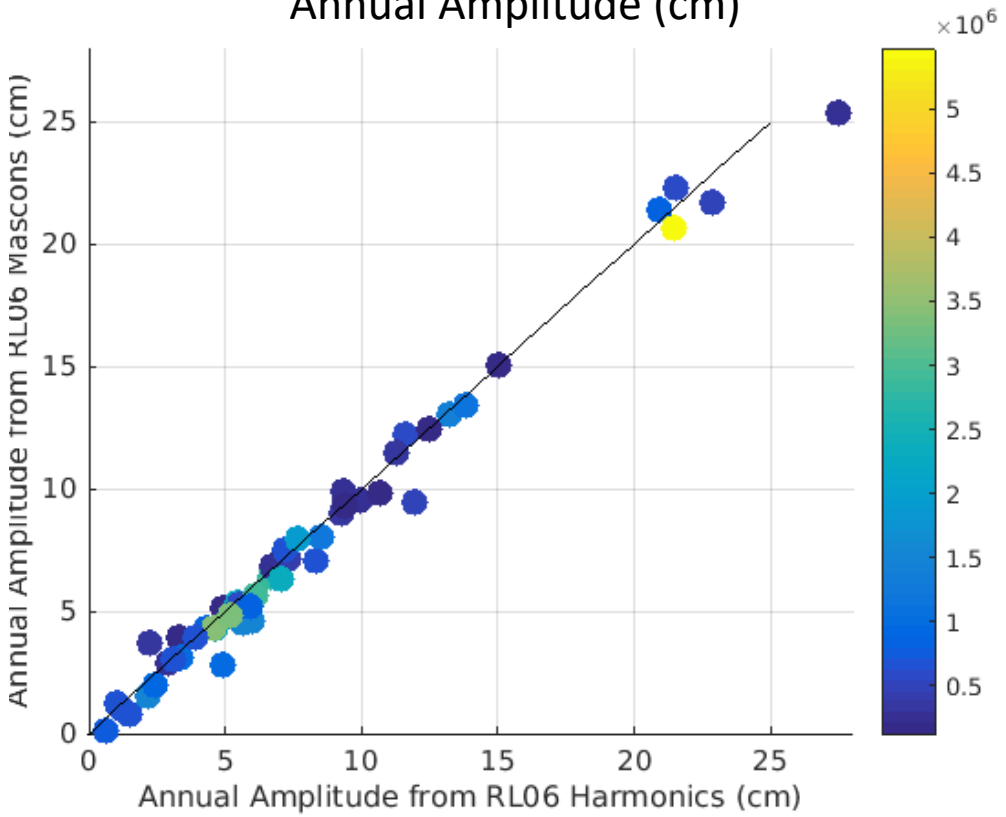
Comparison over 50 hydrological basins

Harmonics have been destriped and smoothed (300 km), and scale factors applied to both solutions

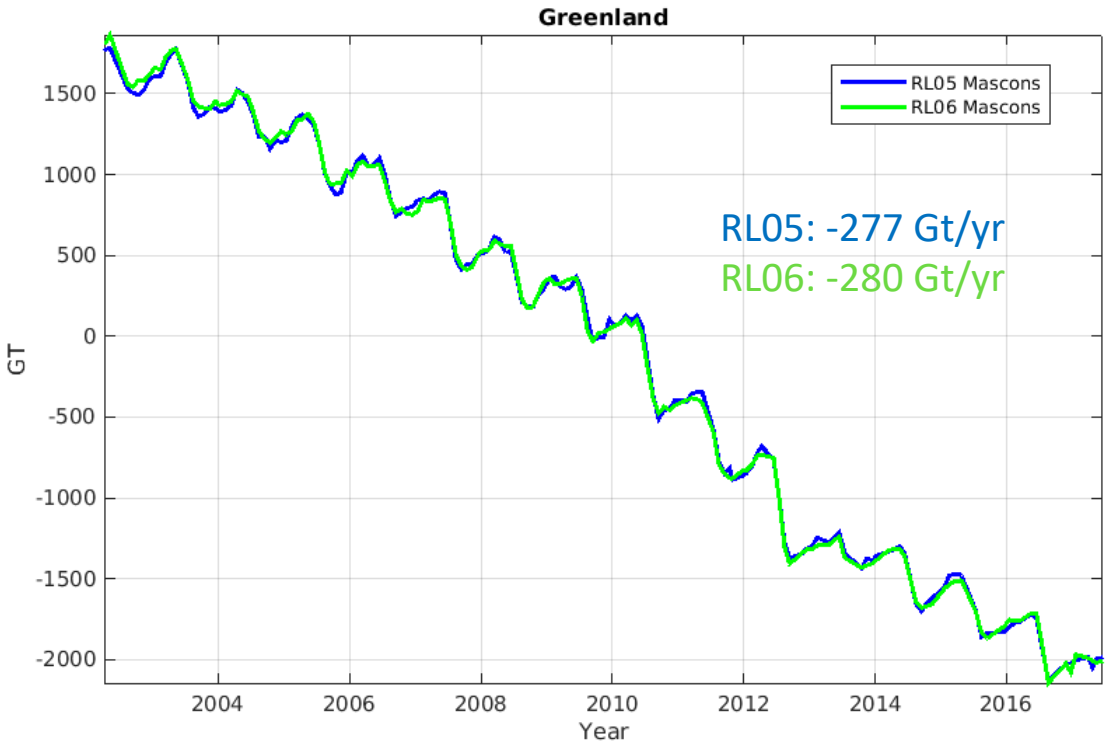
Trend (cm/yr)

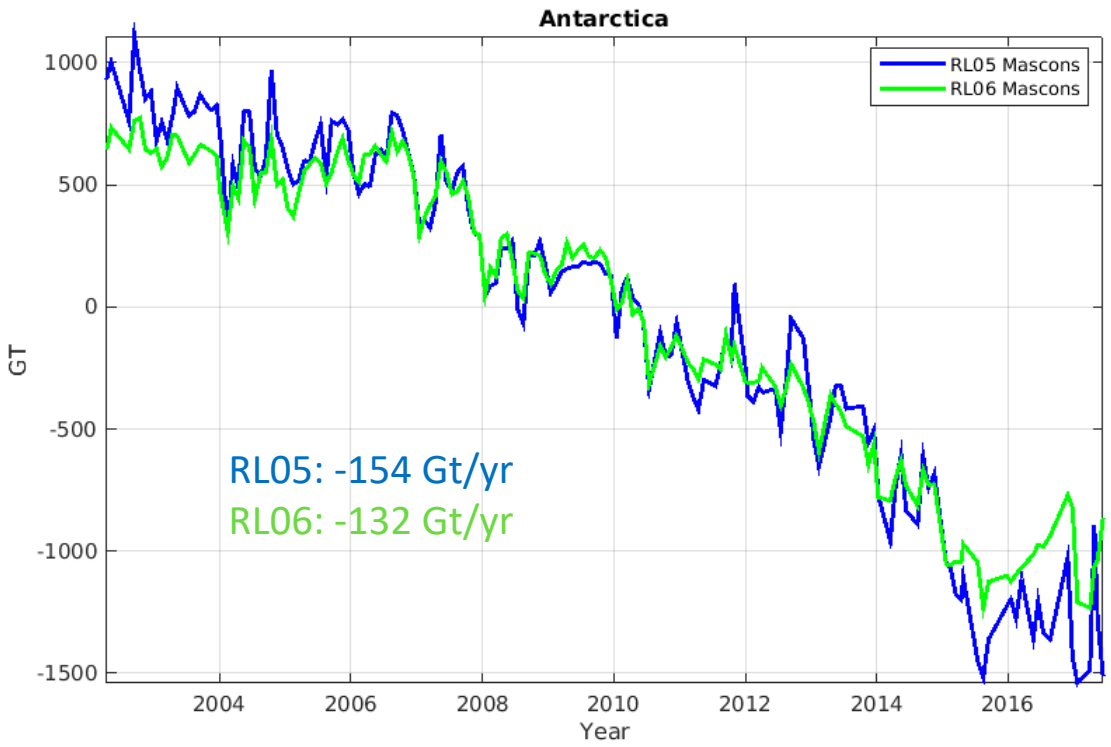


Annual Amplitude (cm)

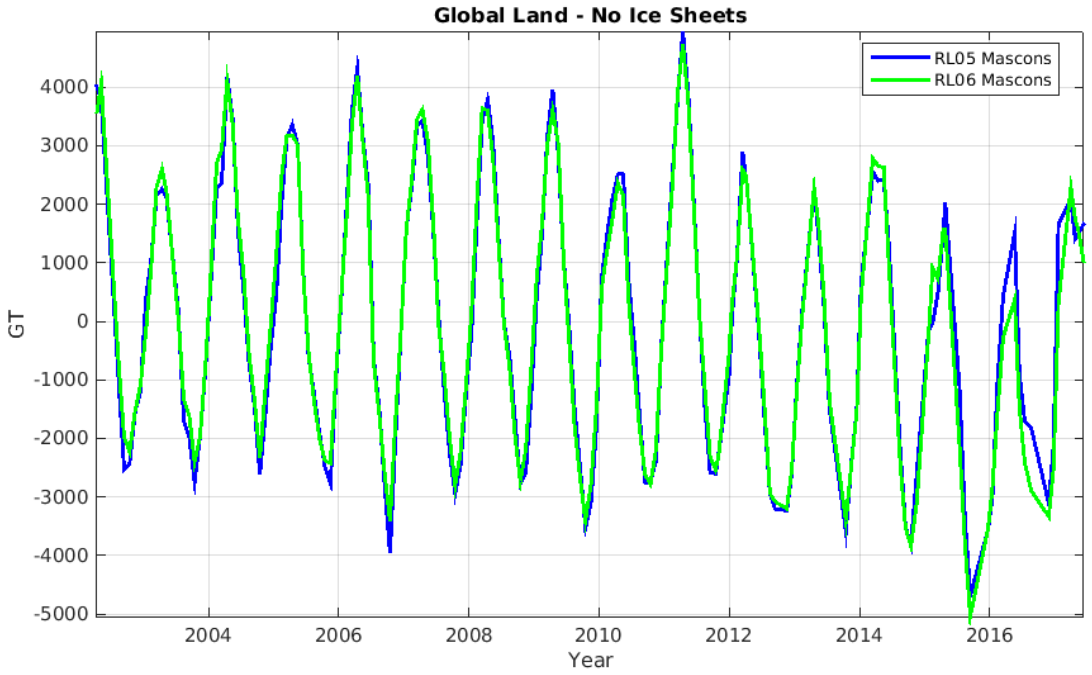


Ice Sheets: RL05 vs. RL06

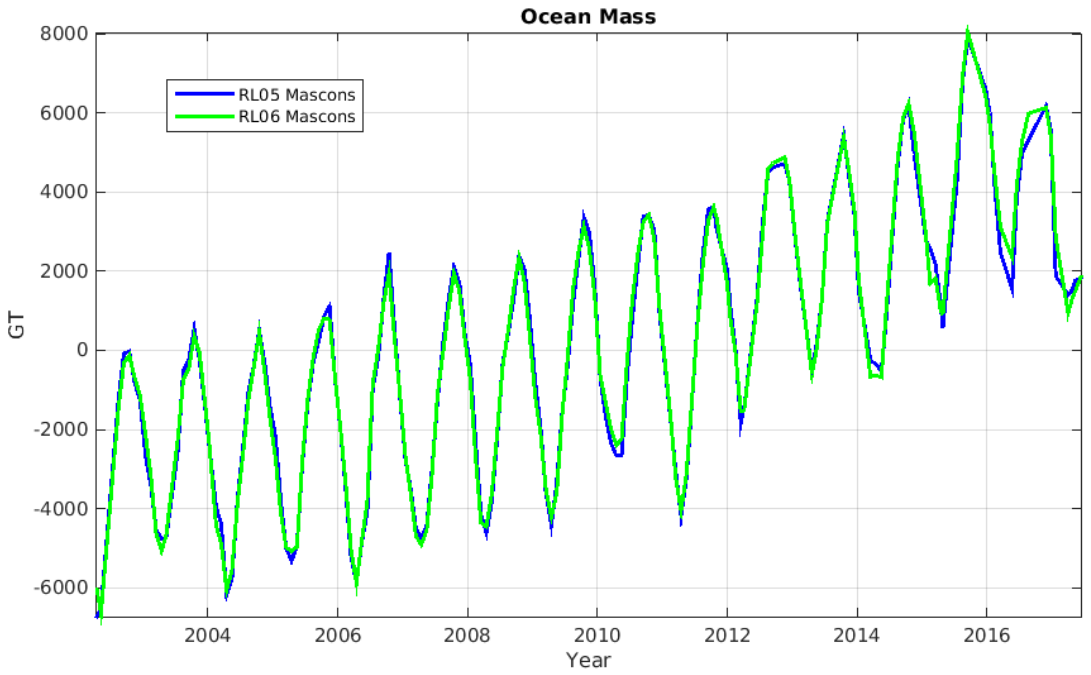




Land/Ocean: RL05 vs. RL06



RL05: -0.33 mm SLE/yr
RL06: -0.42 mm SLE/yr



RL05: 1.59 mm SLE/yr
RL06: 1.62 mm SLE/yr

Conclusions

- JPL RL06 Data products are now (or soon will be) available for use
- RL06 Harmonics represent a large improvement over RL05
  - Still some issues with low degree coefficients during single accelerometer months
- RL06 Mascons improve over RL05 Mascons
  - Better estimate of C_{20}
  - Reduction in residual noise in the solution
  - Reasonable estimates for low degree coefficients during single accelerometer months – this provides for better continuity with GRACE-FO